

A histological study of the lingual molariform teeth in *Hyperopisus bebe* (Mormyridae; Osteoglossomorpha)

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Abstract. – The molariform teeth of the mormyrid fish *Hyperopisus bebe* display a cone of orthodentine overlaid at their tip by a thick layer of enameloid (= acrodine). The teeth are fixed on a cellular bony tissue. This organization is classical for an actinopterygian and fits with the pattern classically observed in other osteoglossiform fishes. The presence of plicidentine and the hyoid tooth and tooth-plate morphology of this species may be related with crushing feeding habits.

Résumé. – Étude histologique des dents molariformes linguales de *Hyperopisus bebe* (Mormyridae ; Osteoglossomorpha).

Les dents molariformes du mormyridé *Hyperopisus bebe* ont une organisation histologique classique : un cône d'orthodentine coiffé d'une épaisse couche d'émailloïde (= acrodine). Les dents sont fixées sur une base d'os cellulaire, ce qui est en accord avec la position phylogénétique de cette espèce parmi les Ostéoglossiformes. La présence de plicidentine ainsi que la morphologie de la plaque linguale et de ses dents peuvent être liées au régime durophage de l'espèce.

Key words

Actinopterygii
Hyperopisus bebe
Tooth
Acrodine
Orthodentine
Plicidentine

3D-models based on tomograph CT-scans allowed the detection of well-developed simple dentine folds in the pulp cavity of the caniniform jaw teeth of *Latimeria chalumnae* (Meunier *et al.*, 2015b). This method also confirmed the presence of more complex dentine folds (polyplocodont plicidentine; Schultze, 1969, 1970) in jaw teeth of extant Lepisosteidae (Germain *et al.*, 2016; Meunier and Brito, 2017), and documented the presence of plicated dentine in the pulp cavity in several teleost fishes (Germain *et al.*, 2016), all of them having predatory habits. This is notably the case of the molariform hyoid teeth of *Hyperopisus bebe* (Lacepède, 1803), an African mormyrid fish, the teeth of which show sharp plies at the base of the pulp cavity (Germain *et al.*, 2016: fig. 4). In the living *H. bebe*, the enlarged tooth hyoid plate faces a broadened parasphenoid that bears the same kind of molariform teeth (Taverne, 1972: fig. 35).

Thus, 3D-imaging based on CT-scan microtomography is well fitted to study the distribution of plicidentine, notably among the huge actinopterygian clade and leads to suggest relationships with feeding habits and probable mechanical constraints rather than a phylogenetic heritage. This tech-

nique has the supplementary advantage to be not invasive and thus to preserve the specimen integrity suitable for rare extant or extinct specimens. However, classical histological techniques, as for instance ground sections, remain compulsory to investigate the fine nature of the tissues. Indeed, CT-scans performed with histological aims have a resolution that rarely goes below 3 µm per voxel, while such histological data are necessary to interpret accurately 3D models.

In the present paper, we detail the histological organization of the molariform teeth and related histology of the lingual tooth plate (= hyoid tooth plate) of *H. bebe*, with the twofold interest for further studies. First, this study provides original details on the teeth and tooth plate histology in a teleost fish with euryphagous diet, which may include crustaceans, algae and macrophyte seeds (Lauzanne, 1976; Malami *et al.*, 2007) and not with a strictly ichthyophagous diet. Second, *H. bebe* is the only extant mormyrid having such a huge biting toothed patch onto the parasphenoid (Taverne, 1971, 1972). Therefore, histological descriptions may be of interest for further discussion on the debated osteoglossiform phylogeny notably to resolve the status of numerous fossils and dentition evolution (*e.g.* Hilton, 2003; Lavoué and Sullivan, 2004).

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MATERIAL AND METHODS

Material

The hyoid tooth-plate was withdrawn from a dry skeleton of *H. bebe* (280 mm TL). The specimen was bought on the fish market in N'Djamena (Chad) and prepared as a dry skeleton by dissection. It belongs to the research dry skeleton collection of O. Otero (number OO-DS-17).

Methods

The material was embedded in polyester resin and sectioned using a sawing machine: the lingual tooth-plate was cut to obtain four fragments *a*, *b*, *c* and *d* (Fig. 1A). The fragment *a* was sectioned horizontally and fragment *b* transversely to obtain respectively transverse and axial sections of the teeth. The ground sections were polished to a thickness of about 60–80 µm and observed under transmitted natural

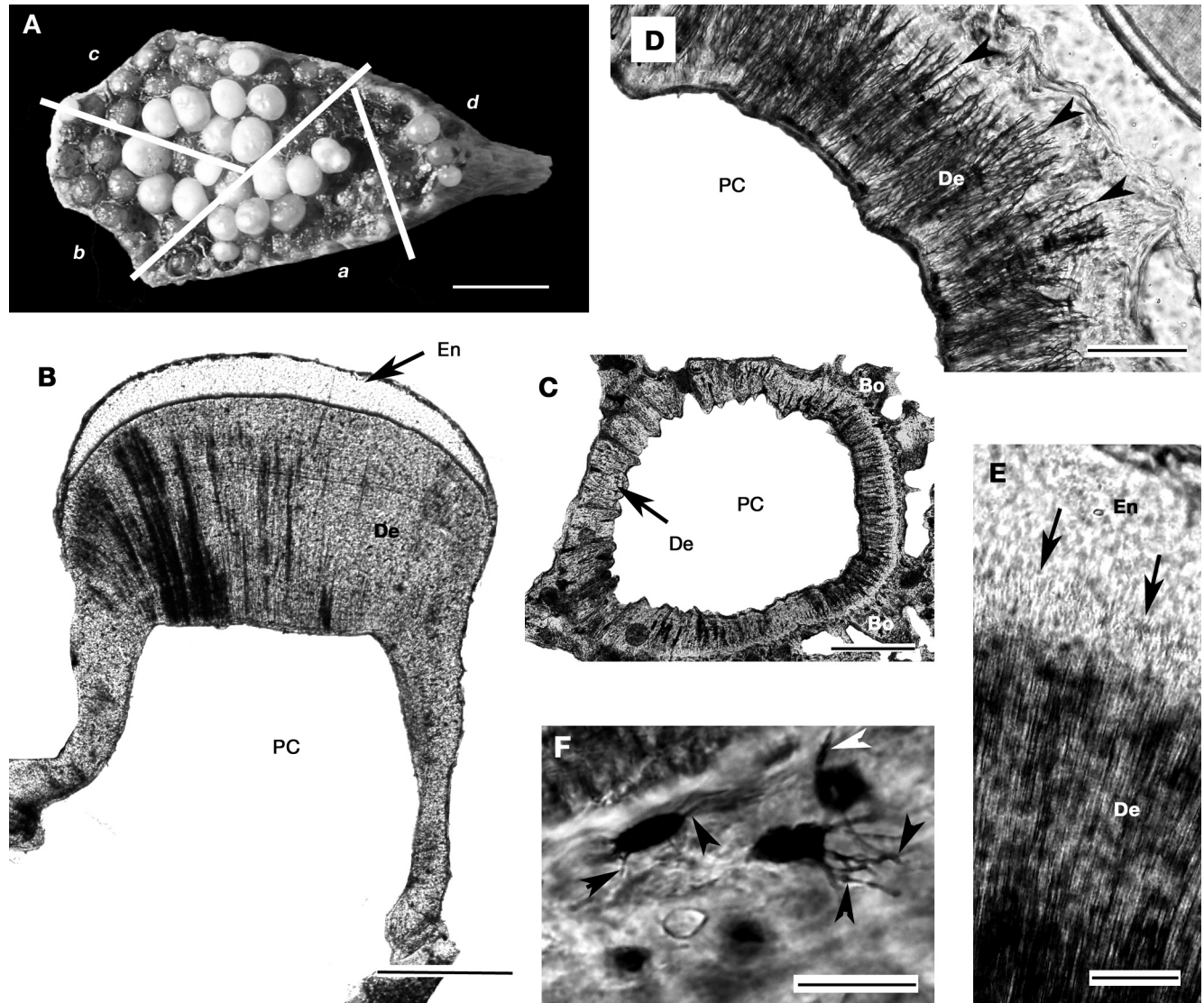


Figure 1. – *Hyperopisus bebe*. A: Dorsal view of the lingual tooth-plate showing the molariform teeth. The three lines indicate the sections of the jaw to obtain the four parts *a*, *b*, *c* and *d*. B: Axial ground section of a tooth (natural transmitted light). The pulp cavity (PC) is surrounded by a massive core of stratified dentine (De), overlaid by a thick apical cape of enameloid (En). C: Cross section of the basal part of a tooth showing the dentine (De) and the bone of attachment (Bo). The dentine wall shows some more or less sharp evaginations (arrowheads) in the pulp cavity (PC). D: Cross section showing a detail of the dentine layer (De) that looks gently laminated, and the parallel odontoblastic canalicles (arrowheads) that are orthogonal to the wall of the pulp cavity (PC). E: Axial section with a detail of the odontoblastic canalicles, some of which being penetrating (arrows) in the enameloid layer (En). F: Cross section with a detail of the tooth supporting bone that shows some osteocytes and their ramified processes (arrowheads). Scale bars: A = 2.5 mm; B, C = 500 µm; D = 100 µm; E = 50 µm; F = 25 µm.

and polarized lights with a Zeiss Axiovert 35 microscope. Pictures were taken with a digital camera Olympus Camedia C-5060.

RESULTS-DISCUSSION

Morphology of the teeth

The hyoid teeth of *H. bebe* are bigger and more numerous than onto the jaws, where six to 11 small teeth are present (Taverne, 1972; Bigorne, 2003). The hyoid tooth-plate is diamond shaped and bears two dozens of densely packed white and rounded functional teeth surrounded by younger non-functional teeth that appear in grey (Fig. 1A). Anteriorly, close to the left edge of the plate, a space, devoid of tooth, corresponds to fallen teeth, which are still not replaced by new ones (Fig. 1A).

The functional teeth are rounded, and measure between 1 mm and 1.5 mm in diameter and between 1.5 and 2 mm in height. Some have a perfectly circular outline whereas others display a weakly deflated occlusal surface, possibly because of the lack of space when they erupted (Fig. 1A). This hyoid tooth and tooth patch morphology are generally related with crushing feeding mechanics. *Hyperopisus bebe* is described as having an opportunistic euryphagous diet that includes soft food and tough materials such as crustaceans, macrophyte seeds (Lauzanne, 1976; Malami *et al.*, 2007), but also molluscs (Lauzanne, 1976; Bailey, 1994). The crushing specialization of the hyoid teeth and tooth patch of *H. bebe* would be well adapted to these various diets. In contrast to *H. bebe*, numerous other mormyrids (like *Brienomyrus*, *Marcusenius*, *Petrocephalus*, *Pollimyrus*), that feed primarily on benthic invertebrates, in which copepods and chironomid larvae predominate (Hyslop, 1986; King, 1989), have a relatively sharper morphology of hyoid teeth (Taverne, 1971, 1972).

Tooth histology

Each tooth is constituted of a thick and round cone of dentine surrounding a relatively large pulp cavity (Fig. 1B). Thin canaliculi are present in the dentine orthogonally to the wall of the pulp cavity (Fig. 1D) and penetrate deeply into the dentine matrix that is delicately laminated (Fig. 1B, D). The presence of these canaliculi indicates that the odontoblasts withdrew during dentine matrix formation and that they remained onto the growing inner surface of the pulp cavity (Ørvig, 1967). This organization characterizes orthodentine. The tooth dentine is overlaid by a thick apical cap of enameloid (Fig. 1B), which is also penetrated by some odontoblastic canaliculi, at least in its basal part close to the dentine surface (Fig. 1E). As such, this enameloid cover can be considered as an acrodine-like cap (Ørvig, 1973 in Ørvig, 1978a, b). The hyoid molariform teeth of *H. bebe* differ in

their fine dentine organization (orthodentine) from what is observed in the molariform teeth of sparids, that are constituted of vasodentine (Hughes *et al.*, 1994), *i.e.* a dentinous tissue crossed by vascular canals but devoid of odontoblastic canaliculi (Lison, 1954; Peyer, 1968). At the base of the pulp cavity, the inner surface of the dentine wall shows discrete and irregular evaginations (Fig. 1C) that correspond to the dentine plies described by 3D-modelization (Germain *et al.*, 2016: fig. 4). These plies are simple, lack any secondary plicated structure, and do not invade the pulp cavity. As such, the plicidentine of the hyoid teeth of *H. bebe* is assigned to the simplexodont type of plicidentine according to the classification of Meunier *et al.* (2015a).

The plicated organization of the dentine walls of the hyoid dentition of *H. bebe* is assumed to be a response to mechanical constraints during crushing the food. In conclusion, with the exception of this feature, the hyoid teeth of *H. bebe* exhibit a histological organization classical for an actinopterygian fish, including an apical acrodine cap covering orthodentine (Lison, 1954; Ørvig, 1967, 1978a, b; Poole, 1967; Peyer, 1968; Meunier *et al.*, 2018).

Bone histology

The teeth are fixed on a vascularized supporting bone that contains star-shaped osteocytic lacunae with ramified osteocytic canaliculi (Fig. 1F). Thus, *H. bebe* possesses cellular bone (= osteocytic bone), as all other Osteoglossiformes, for which bony histological data are available (*e.g.* Kölliker, 1859; Moss, 1965; Meunier *et al.*, 2013).

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REFERENCES

- BAILEY R.G., 1994. - Guide to the fishes of the River Nile in the Republic of the Sudan. *J. Nat. Hist.*, 28: 937-970.
- BIGORNE R., 2003. - Mormyridae. In: Poissons d'Eaux douces et saumâtres de l'Afrique de l'Ouest – The Fresh and Brackish Water Fishes of West Africa (Paugy D., Lévêque C. & Teugels G.G., eds), Vol. 1: 155-222. Collection Faune et flore tropicales, IRD Éditions, MNHN, MRAC.
- GERMAIN D., MONDÉJAR-FERNÁNDEZ J. & MEUNIER F.J., 2016. - The detection of plicidentine tooth organisation in teleostean fishes owing to non-destructive tomography. *Cybium*, 40(1): 75-82.
- HILTON E.J., 2003. - Comparative osteology and phylogenetic systematics of fossil and living bony-tongue fishes (Actinopterygii, Teleostei, Osteoglossomorpha). *Zool. J. Linn. Soc.*, 2003, 137: 1-100.

- HUGHES D.R., BASSETT J.R. & MOFFAT L.A., 1994. - Structure and origin of the tooth pedicel (the so-called bone of attachment) and dental-ridge bone in the mandibles of the sea breams *Acanthopagrus australis*, *Pagrus auratus* and *Rhabdosargus sarba* (Sparidae, Perciformes, Teleostei). *Anat. Embryol.*, 189: 51-69.
- HYSLOP E.J., 1986. - The food habits of four small-sized species of Mormyridae from the flood plain pools of the Sokoto-Rima river basin. *Cybium*, 28(2): 147-151.
- KING R.P., 1989. - Distribution, abundance, size and feeding habits of *Brienomyrus brachyistius* (Gill, 1862) (Teleostei: Mormyridae) in a Nigerian rainforest stream. *Cybium*, 13(1): 25-36.
- KÖLLIKER A., 1859. - On the different types in the microscopic structure of the skeleton of the osseous fish. *Proc. R. Soc. Lond.*, 9: 656-688.
- LAUZANNE L., 1976. - Régimes alimentaires et relations trophiques des poissons du lac Tchad. *Cah. ORSTOM, sér. Hydrobiol.*, 10(110): 267-310.
- LAVOUÉ S. & SULLIVAN J.P., 2004. - Simultaneous analysis of five molecular markers provides a well-supported phylogenetic hypothesis for the living bony-tongue fishes (Osteoglossomorpha: Teleostei). *Mol. Phylogenet. Evol.*, 33: 171-185.
- LISON L., 1954. - Les dents. In: *Traité de Zoologie* (Grassé P.P., ed.), Vol. 12: 791-853. Masson, Paris.
- MALAMI G.Z., IPINJOLU J.K., HASSAN W.A. & MAGAWATA I., 2007. - Food and Feeding Habit of Fresh water Mormyrid *Hyperopisus bebe occidentalis* in River Rima and Goronyo Dam, Nigeria. *Proc. of the Fisheries Society of Nigeria held at Kebbi State*, 12-16th Nov. 2007.
- MEUNIER F.J. & BRITO P.M., 2017. - Histological characteristics of lower jaws and oral teeth in the extant Lepisosteidae, *Lepisosteus platostomus* Rafinesque, 1820. *Cybium*, 41(3): 279-286.
- MEUNIER F.J., BRITO P.M. & LEAL M.E., 2013. - Quelques données morphologiques et histologiques sur la structure de la plaque dentaire linguale d'*Arapaima gigas* (Osteoglossidae; Teleostei). *Cybium*, 37(4): 263-271.
- MEUNIER F.J., DE MAYRINCK D. & BRITO P.M., 2015a. - Presence of plicidentine in the labial teeth of *Hoplias aimara* (Erythrinidae; Ostariophysi; Teleostei). *Acta Zool.*, 96: 174-180.
- MEUNIER F.J., MONDEJAR-FERNANDES J., GOUSSARD F., CLÉMENT G. & HERBIN M., 2015b. - Presence of plicidentine in the oral teeth of *Latimeria chalumnae* (Sarcopterygii; Actinistia; Coelacanthidae). *J. Struct. Biol.*, 190(1): 31-37.
- MEUNIER F.J., OTERO O. & LAURIN M., 2018. - A histological study of the jaw teeth in the Devonian actinopterygian *Cheirolepis canadaensis* (Whiteaves). *Cybium*, 42(1): 67-74.
- MOSS M.L., 1965. - The biology of acellular teleost bone. *Ann. N.Y. Acad.*, 109: 337-350.
- ØRVIG T., 1967. - Phylogeny of tooth tissues: evolution of some calcified tissues in early Vertebrates. In: *Structural and Chemical Organization of Teeth* (Miles A.E.W., ed.), Vol. 1: 45-110. New York: Academic Press.
- ØRVIG T., 1978a. - Microstructure and growth of the dermal skeleton in fossil actinopterygian fishes: *Bigeria* and *Scanilepis*. *Zool. Scripta*, 7: 33-56.
- ØRVIG T., 1978b. - Microstructure and growth of the dermal skeleton in fossil actinopterygian fishes: *Nephrotus* and *Colobodus*, with remarks on the dentition in other forms. *Zool. Scripta*, 7: 297-326.
- PEYER B., 1968. - Osteichthyes. In: *Comparative Odontology* (Zangerl R., ed.), pp. 80-110. Univ. Chicago Press.
- POOLE D.F.G., 1967. - Phylogeny of tooth tissues: enameloid and enamel in recent vertebrates, with a note on the history of cementum. In: *Structural and Chemical Organization of Teeth* (A.E.W. Miles, ed.), pp. 111-149. New-York: Academic Press.
- SCHULTZE H.P., 1969. - Die Faltenzähne der Rhipidisiiden Crossopterygier, der Tetrapoden und der Actinopterygier-Gattung *Lepisosteus* nebst einer Beschreibung der Zahnstruktur von *Onichodus* (Strunioformer Crossopterygier). *Palaeontol. Ital.*, New Ser. 35, 65: 63-137.
- SCHULTZE H.P., 1970. - Folded teeth and the monophyletic origin of Tetrapods. *Am. Mus. Novitates*, 2408: 1-10.
- TAVERNE L., 1971. - Ostéologie des genres *Marcusenius* Gill, *Hippopotamyrus* Pappenheim, *Cyphomyrus* Myers, *Pollimyrus* Taverne et *Brienomyrus* Taverne (Pisces, Mormyriiformes). *Ann. Mus. R. Afr. Centr., Sci. Zool.*, 188: 1-144.
- TAVERNE L., 1972. - Ostéologie des genres *Mormyrus* Linné, *Mormyrops* Müller, *Hyperopisus* Gill, *Myomyrus* Boulenger, *Stomatorhinus* Boulenger et *Gymnarchus* Cuvier. Considérations générales sur la systématique des poissons de l'ordre des Mormyriiformes. *Ann. Mus. R. Afr. Centr., Sci. Zool.*, 200: 1-194.